FEMA 120194
ORIGINAL

FLOOD INSURANCE STUDY

WAVE HEIGHT ANALYSIS

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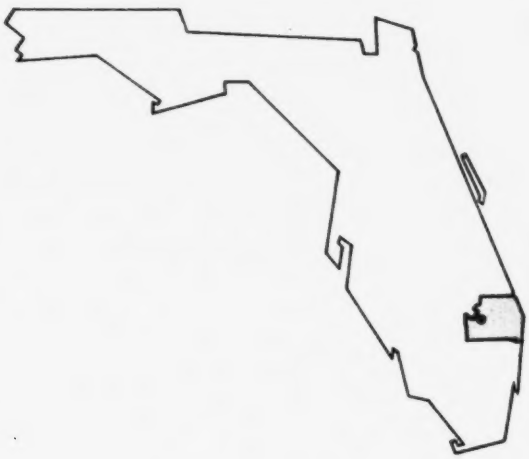
CITY OF BELLE GLADE, FLORIDA
PALM BEACH COUNTY



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Federal Emergency Management Agency

COMMUNITY NUMBER - 120194

ANALYSIS OF WAVE HEIGHTS
FOR
CITY OF BELLE GLADE, PALM BEACH COUNTY, FLORIDA

FEDERAL EMERGENCY MANAGEMENT AGENCY

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1.0 INTRODUCTION

1.1 Background and Purpose

The Federal Emergency Management Agency recently adopted recommendations by the National Academy of Sciences to include prediction of wave heights in Flood Insurance Studies for coastal communities subject to storm surge flooding, and to report the estimated wave crest elevations as the base flood elevations on Flood Insurance Rate Maps (FIRMs).

Previously, FIRMs were produced showing only the stillwater storm-surge elevations due to the lack of a suitable and generally applicable methodology for estimating the wave crest elevations associated with storm surges. These stillwater elevations were subsequently stipulated in community flood plain management ordinances as the minimum elevation of the first floor of new construction. Communities and individuals had to consider the additional hazards of velocity waters and wave action on an ad hoc basis. Because there has been a pronounced tendency for buildings to be constructed only to meet minimum standards, without consideration of the additional hazard due to wave height, increasing numbers of people could unknowingly be accepting a high degree of flood-related personal and property risk in coastal areas subject to wave action. Therefore, the Federal Emergency Management Agency has pursued the development of a suitable methodology for estimating the wave crest elevations associated with storm surges. The recent development of such a methodology by the National Academy of Sciences (Reference 1) has led to the adoption of wave crest elevations for use as the base flood elevations in coastal communities.

The Lake Okeechobee area has been subject to flooding from several hurricanes. The most severe was the storm of September 1928. This hurricane is considered one of the most violent ever to strike Florida. Winds of up to 75 miles per hour were reported at Lake Okeechobee. A wind-driven tidal wave, ranging from 5 to 10 feet, brought about widespread loss of life and destruction of property along the southwest shore of the lake. The hurricane of August 1949 was the worst to hit the Lake Okeechobee area since September 1928. However, the Herbert Hoover Dike, constructed in the early 1930's prevented the occurrence of any flooding.

The City of Belle Glade, Florida, is located on Lake Okeechobee and is subject to flooding from tidal surges associated with hurricanes. The purpose of this study is to revise the FIRM for Belle Glade to include the effects of wave action associated with flooding from Lake Okeechobee.

2.0 INVESTIGATIONS

2.1 Previous Studies

Stillwater elevations for hurricane surges with 10-, 50-, 100-, and 500-year return periods were determined by Tetra Tech, Inc. for all areas

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of Palm Beach County and its incorporated communities inundated by tidal flooding. The 100-year stillwater elevations were used as base flood elevations for the Flood Insurance Study that has been prepared for Belle Glade (Reference 2).

These elevations were determined by the joint probability method (Reference 3). The storm populations were described by probability distributions of five parameters which influence surge heights. These parameters were central pressure depression (which measures the intensity of the storm), radius to maximum winds, forward speed of the storm, shoreline crossing point, and crossing angle. These characteristics were described statistically, based on an analysis of observed storms in the vicinity of Palm Beach County. Primary sources of data for the parameters were the National Weather Service (Reference 4); Cry (Reference 5); Ho, Schwerdt, and Goodyear (Reference 6); and, the National Hurricane Research Project (Reference 7).

A numerical hydrodynamic model of the region was used to simulate the coastal surge generated by any chosen storm (that is, any combination of the five storm parameters defined previously). By performing such simulations for a large number of storms each of known total probability, the frequency distribution of surge height can be established as a function of coastal location. These distributions incorporate the large scale surge behavior, but do not include an analysis of the added effects associated with much finer scale wave phenomena, such as wave height, setup, or runup. The astronomical tide for the region was statistically combined with the computed storm tide to yield recurrence intervals of total water level.

The stillwater elevations developed for the previous Flood Insurance Study were used as starting water-surface elevations for the wave height analysis presented herein.

This report is authoritative for purposes of the National Flood Insurance Program. Data presented herein supersedes all previous flood elevation determinations.

2.2 Data Collection and Review

All available source data applicable for the wave height analysis were collected and reviewed. Because wave height calculations are based on such parameters as the size and density of vegetation, natural barriers (such as sand dunes), buildings, and other manmade structures, it was necessary to obtain detailed information on the physical and cultural features of the study area.

Officials of the City of Belle Glade and Palm Beach County were contacted for maps and other possible data sources to be used in the analysis. In addition, the Florida Department of Transportation; the Florida Department of Natural Resources, Bureau of Beaches and Shores; the U.S. Army Corps of Engineers, Jacksonville District; the National Ocean Survey; the U.S. Fish and Wildlife Service; and the South Florida Water Management District were contacted and all applicable data sources were obtained.

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The principal source materials used for the wave height analysis are described below.

a. Topographic data (ground elevations, seawall elevation, and locations of physical features) were determined using U.S. Geological Survey topographic maps at a scale of 1:24,000, with a contour interval of 5 feet (Reference 8); National Ocean Survey storm evacuation maps at a scale of 1:62,500, with a contour interval of 5 feet (Reference 9); a spot elevation map received from the South Florida Water Management District (Reference 10); and a nautical chart of Lake Okeechobee at a scale of 1:80,000, obtained from the National Ocean Survey (Reference 11).

b. Stereoscopic aerial photography at a scale of 1:6,000 and National Wetlands Inventory Maps at a scale of 1:24,000 were used to determine vegetation and building parameters and to supplement the topographic maps for locations of physical features (References 12 and 13).

2.3 Wave Height Analysis

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in the National Academy of Sciences report (Reference 1). This method is based on the following major concepts. First, depth-limited waves in shallow water reach a maximum breaking height that is equal to 0.78 times the stillwater depth. The wave crest is 70 percent of the total wave height above the stillwater level. The second major concept is that wave height may be diminished by dissipation of energy due to the presence of obstructions, such as sand dunes, dikes and seawalls, buildings, and vegetation. The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures prescribed in Reference 1. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

Wave heights were computed along transects (cross section lines) in accordance with the Users Manual for Wave Height Analysis (Reference 14). The transects were located along the coastline as shown in Figure 1. They were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, they were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Each transect was taken perpendicular to the shoreline and extended to the inland limit of tidal flooding. Along each transect, wave heights and elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The stillwater elevations for the 100-year flood were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were

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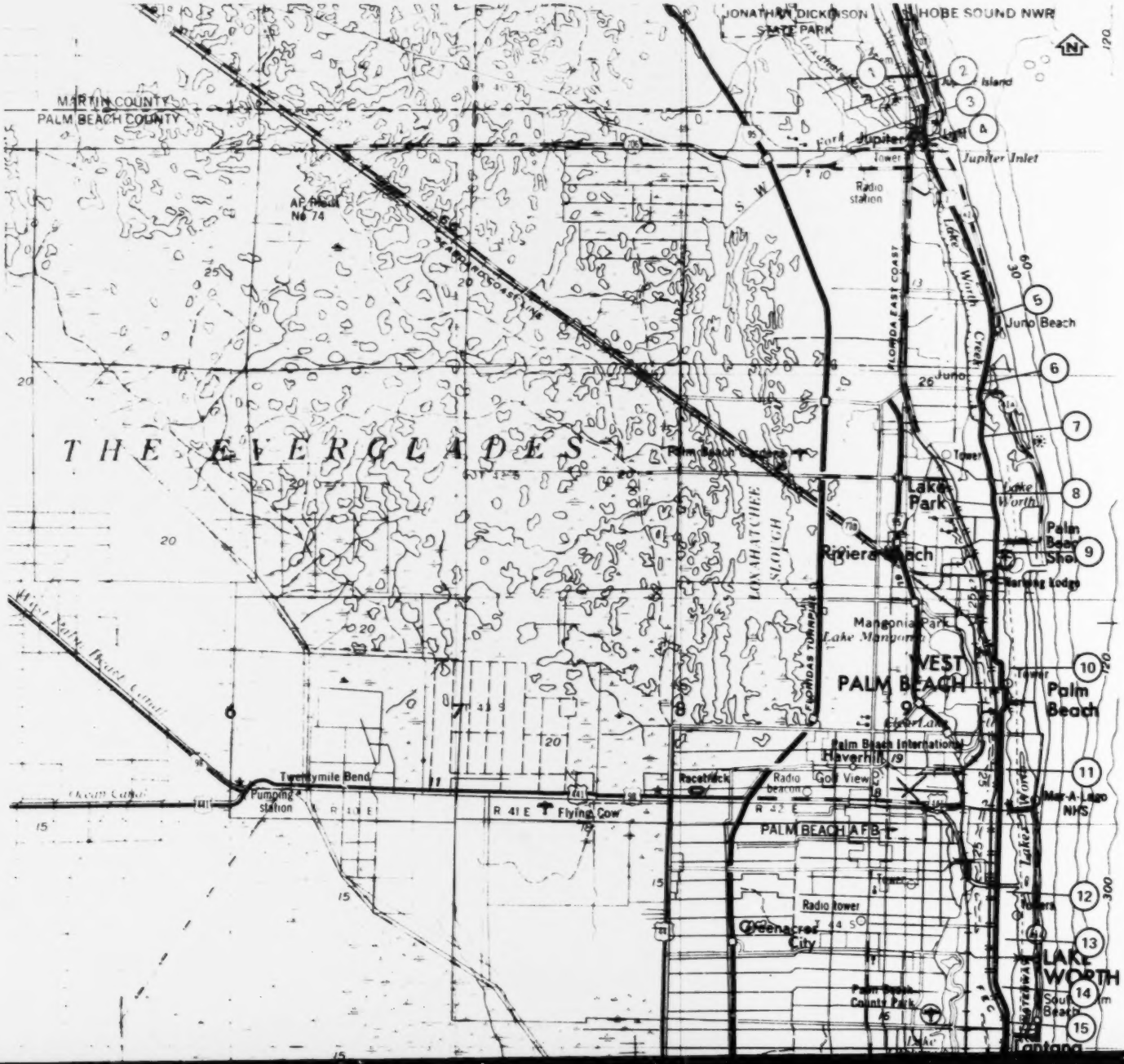

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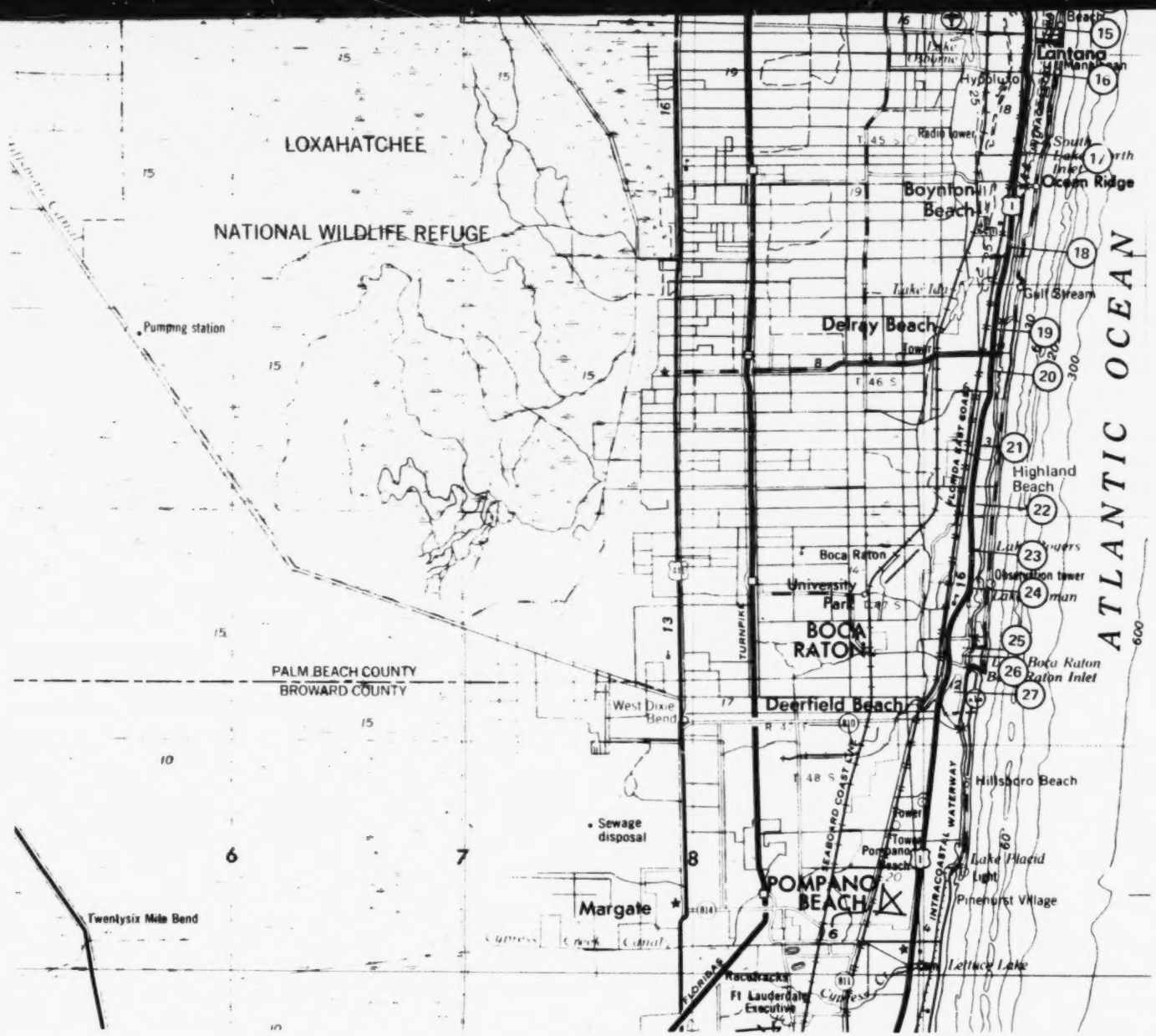

FIGURE 1A

FEDERAL EMERGENCY MANAGEMENT AGENCY

PALM BEACH COUNTY, FL

APPROXIMATE SCALE

4 0 4 8 12 MILES

TRANSECT LOCATION MAP

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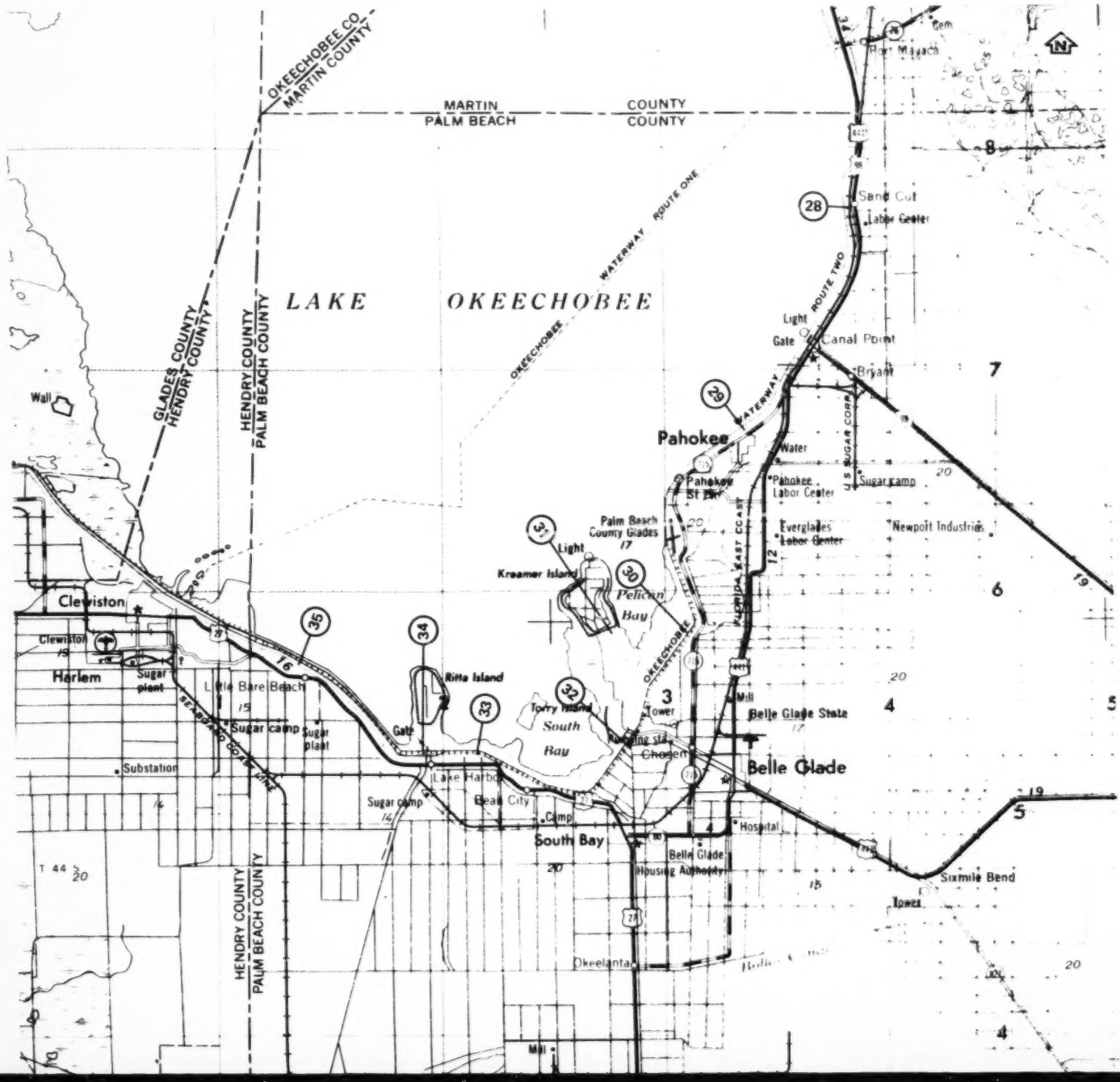

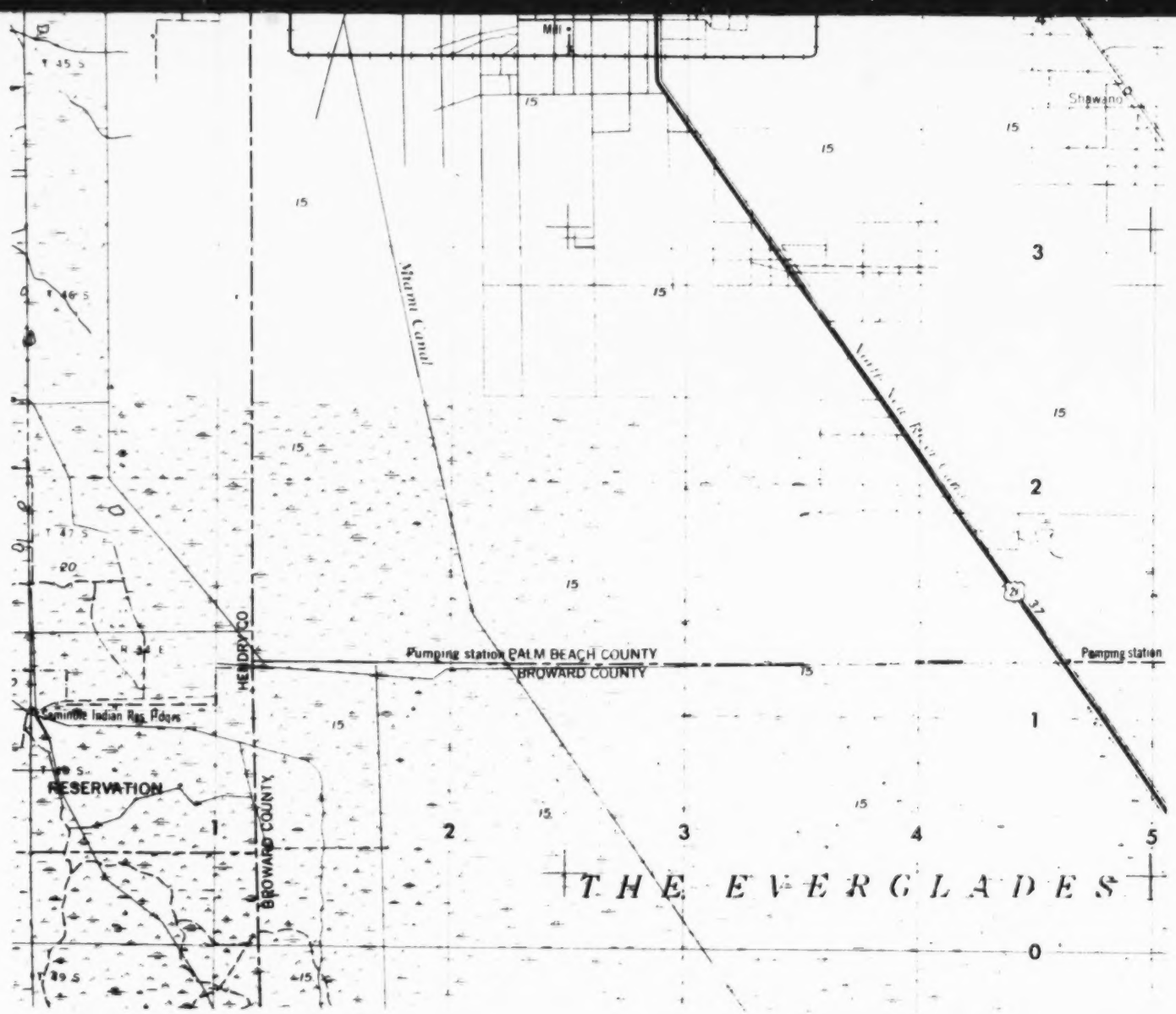

FIGURE 1B

FEDERAL EMERGENCY MANAGEMENT AGENCY

PALM BEACH COUNTY, FL

APPROXIMATE SCALE

4 0 4 8 12 MILES

TRANSECT LOCATION MAP

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determined at whole-foot increments along the transects. The location of the 3-foot breaking wave for determining the terminus of the V Zone (area with velocity wave action) was also computed at each transect. Table 1 provides a listing of the transect locations and stillwater elevations, as well as maximum wave crest elevations in the vicinity of Belle Glade.

Figure 2 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in Belle Glade may not necessarily include all the situations illustrated in Figure 2.

After analyzing wave heights along each transect, wave elevations were interpolated between transects. Various source data were used in the interpolation, including topographic maps (References 8, 9, and 10) and aerial photographs (Reference 12), along with engineering judgment. Controlling features affecting the elevations were identified and considered in relation to their positions at a particular transect and their variation between transects.

2.4 Results

Belle Glade is afforded protection from Lake Okeechobee flooding by the Herbert Hoover Dike, which is expected to remain intact during the 100-year storm surge. This structure will not be overtopped.

The only portion of Belle Glade affected by wake action is located on Torry Island. The breaking wave crest elevation at the shoreline of Lake Okeechobee at Torry Island, outside Belle Glade, is 31 feet. This elevation is diminished by levees and vegetation on Kreamer and Torry Islands to 27 feet. All wave action stops abruptly at the Herbert Hoover Dike.

3.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

A prime purpose of the National Flood Insurance Program is to encourage local governments to adopt sound flood plain management programs designed to reduce future flood losses. The FIRM for Belle Glade has been revised to incorporate the latest available information, including wave height data, to assist this community in developing the most appropriate and effective flood plain management measures.

3.1 Flood Boundaries

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by the Federal Emergency Management Agency as the base flood for purposes of flood plain management. This flood has a 1 percent chance of being equalled or exceeded each year and is expected to be exceeded once on the average during any 100-year period. The risk of having a flood of this magnitude or greater increases when periods longer than 1 year are considered. For example, over a 30-year period, there is

Table 1.
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
30	Palm Beach County - Across Lake Okeechobee and Pelican Bay, through the northeastern portion of Torry Island to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike	24.8[1]	31[1]
32	Palm Beach County/Belle Glade - Across Lake Okeechobee and the southern tip of Torry Island to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike in Belle Glade	25.3[1]	28[1]

[1]Lake Okeechobee

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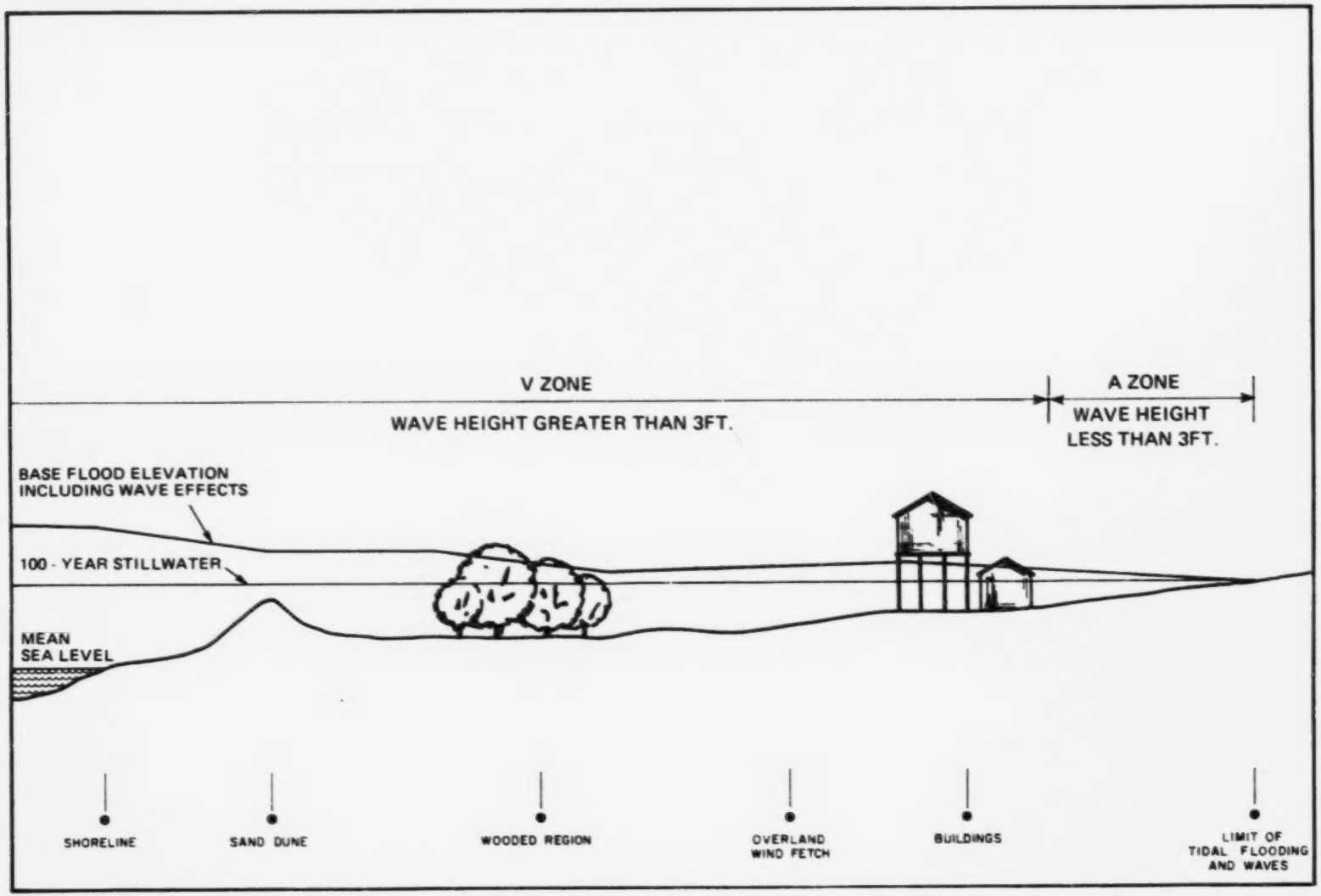

FIGURE 2
TYPICAL TRANSECT SCHEMATIC

a 26 percent chance of experiencing a flood equal to or greater than the 100-year flood. The 500-year flood plain is also shown on the FIRM to indicate areas of moderate flood hazards.

Areas inundated by the 100-year flood are shown as A and V Zones on the community's FIRM. It is in these areas that the Federal Emergency Management Agency requires local communities to exercise flood plain management measures as a condition for participation in the National Flood Insurance Program.

3.2 Base Flood Elevations

Areas within the communities studied by detailed engineering methods have base flood elevations established in A and V Zones. These are the elevations of the base (100-year) flood relative to the National Geodetic Vertical Datum of 1929. In coastal areas affected by wave action, base flood elevations are generally maximum at the open coast shoreline. These elevations generally decrease in a landward direction at a rate dependent on the presence of obstructions capable of dissipating the wave energy. Where possible, changes in base flood elevations have been shown in 1-foot increments on the FIRMs. However, where the scale did not permit, 2- or 3-foot increments were sometimes used. Base flood elevations shown in the wave action areas represent the average elevation within the zone. Current program regulations generally require that all new construction be elevated such that the first floor, including basement, is above the base flood elevation in A and V Zones.

3.3 Velocity Zones

The U.S. Army Corps of Engineers (Reference 15) has established the 3-foot breaking wave as the criterion for identifying coastal high hazard zones. This was based on a study of wave action effects on structures. This criterion has been adopted by the Federal Emergency Management Agency for the determination of V Zones. Because of the additional hazards associated with high-energy waves, the National Flood Insurance Program regulations require much more stringent flood plain management measures in these areas, such as elevating structures on piles or piers. In addition, insurance rates in V Zones are higher than those in A Zones with similar numerical designations.

The location of the V Zone is determined by the 3-foot breaking wave as discussed previously. The detailed analysis of wave heights performed in this study allowed a much more accurate location of the V Zone to be established. The V Zone generally extends inland to the point where the 100-year flood depth is insufficient to support a 3-foot breaking wave.

4.0 INSURANCE APPLICATION

The assignment of proper actuarial insurance rates requires that frequency and depth of flooding be estimated as accurately as possible. Because waves can add considerably to expected flood depths, it is important that insurance

rates consider this additional hazard. The Federal Emergency Management Agency has developed a process to transform the data from this study into flood insurance criteria. This process includes the determination of Flood Hazard Factors and the designation of flood insurance zones.

4.1 Flood Hazard Factors

The Flood Hazard Factor (FHF) is the device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHF are used to set actuarial insurance premium rate tables.

The FHF is shown as a three-digit code that expresses the difference between the 10- and 100-year flood elevations to the nearest 0.5 foot. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year water-surface elevations is greater than 10.0 feet, the FHF is computed to the nearest foot.

4.2 Flood Insurance Zones

After wave elevations for the 100-year storm surge were determined and mapped, the study areas were divided into zones, each having a specific flood potential and FHF. Each zone was assigned one of the following flood insurance zone designations:

Zone V10:	Special Flood Hazard Areas inundated by the 100-year flood, and that have additional hazards due to velocity (wave action); base flood elevations shown, and zones subdivided according to FHFs.
Zone A8:	Special Flood Hazard Areas inundated by the 100-year flood, with base flood elevations determined and zone designations assigned according to the FHFs.
Zone B:	Areas between the Special Flood Hazard Areas and the limits of the 500-year flood plain, including areas that are protected from the 100- and 500-year floods by dike, levee, or other water control structure; and areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot, or where the contributing drainage area is less than 1 square mile. Zone B is not subdivided.

Zone C: Areas not subject to flooding by the 500-year flood. Zone C is not subdivided.

Table 2, "Flood Insurance Zone Data," summarizes the FHFs, flood insurance zones, and base flood elevations for each flooding source in the study area.

4.3 Flood Insurance Rate Map

After flood insurance zones were established for the study area, the FIRM for Belle Glade was revised to incorporate the new zone information. This map (Exhibit 1) contains the official delineation of flood insurance zones and base flood elevations.

In preparing the revised FIRM, updated topographic information was used to revise some zone boundaries in areas not affected by the wave height analysis. Corporate limits and cultural features were revised using a current community map (Reference 16).

5.0 OTHER STUDIES

The FIRM for Palm Beach County is being revised concurrently with Belle Glade to include wave height analysis. The revised study for Palm Beach County will be in agreement with this study.

6.0 REFERENCES

1. National Academy of Sciences, Methodology for Calculating Wave Action Effects Associated With Storm Surges, 1977

2. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Belle Glade, Florida, 1978

3. U.S. Department of Commerce, Environmental Science Services Administration, Technical Memorandum WBTM Hydro 11, Joint Probability Method of Tide Frequency Analysis, V.A. Myers, April 1970

4. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Tropical Cyclone Deck 993, 1975

5 U.S. Department of Commerce, Weather Bureau, Technical Paper No. 55, Tropical Cyclones of the North Atlantic Ocean 1871 - 1963, G.W. Cry, 1965

6. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Technical Report NWS-15, Climatological Characteristics of Hurricanes, F.P. Ho, R.W. Schwerdt, and H.V. Goodyear, July 1975

7. U.S. Department of Commerce, National Hurricane Research Project, Report No. 5, Survey of Meteorological Factors, March 1957

Table 2. Flood Insurance Zone Data

Flooding Source	Stillwater Elevation 10-Year	50-Year	100-Year	500-Year	FHF	Zone	Base Flood Elevation (Feet NGVD)*
Lake Okeechobee	21.5	24.2	25.3	26.6	050	VI0	27,28
					040	A8	25 to 27

*Due to map scale limitations, base flood elevations shown on the FIRM may represent average elevations for the zones depicted.

8. U.S. Department of the Interior, Geological Survey, 7.5-Minute Series Topographic Maps, Scale 1:24,000, Contour Interval 5 feet: Belle Glade, Florida (1970)

9. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Storm Evacuation Maps T-15088 and T-15090, Scale 1:62,500, Contour Interval 5 feet: Belle Glade, Florida (1978); Okeechobee, Florida (1978)

10. South Florida Water Management District, Map showing spot elevations of the Belle Glade Marina and Herbert Hoover Dike in the vicinity of Belle Glade, Florida, scale 1:2,400, July 1981

11. National Oceanic and Atmospheric Administration, National Ocean Survey, Nautical Chart 11428, St. Lucie Inlet to Ft. Myers and Lake Okeechobee, Florida, Scale 1:80,000, 1980

12. U.S. Army Corps of Engineers, Aerial Photography of Lake Okeechobee, Florida, Scale 1:6,000, December 1975

13. U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory Maps, Scale 1:24,000: Belle Glade, Florida (unpublished)

14. Federal Emergency Management Agency, Users Manual for Wave Height Analysis, Revised February 1981

15. U.S. Department of the Army, Corps of Engineers, Galveston District, Guidelines for Identifying Coastal High Hazard Zones, June 1975

16. Belle Glade Chamber of Commerce, Belle Glade, Florida, undated

U.S. Department of Housing and Urban Development, Federal Insurance Administration, Coastal Flooding Handbook, Parts I and II, Tetra Tech, Inc., May 1977